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Impact of temperature on childhood pneumonia estimated from satellite remote sensing ☆

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ABSTRACT

The effect of temperature on childhood pneumonia in subtropical regions is largely unknown so far. This study examined the impact of temperature on childhood pneumonia in Brisbane, Australia. A quasi-Poisson generalized linear model combined with a distributed lag non-linear model was used to quantify the main effect of temperature on emergency department visits (EDVs) for childhood pneumonia in Brisbane from 2001 to 2010. The model residuals were checked to identify added effects due to heat waves or cold spells. Both high and low temperatures were associated with an increase in EDVs for childhood pneumonia. Children aged 2–5 years, and female children were particularly vulnerable to the impacts of heat and cold, and Indigenous children were sensitive to heat. Heat waves and cold spells had significant added effects on childhood pneumonia, and the magnitude of these effects increased with intensity and duration. There were changes over time in both the main and added effects of temperature on childhood pneumonia. Children, especially those female and Indigenous, should be particularly protected from extreme temperatures. Future development of early warning systems should take the change over time in the impact of temperature on children's health into account.

1. Introduction

Climate change has been widely recognized as the biggest health threat in the 21st century (McMichael, 2013), and its possible impact on infectious disease has attracted public health attention (Altizer et al., 2013). Children, particularly their respiratory system (Sheffield and Landrigan, 2011), are vulnerable to the adverse impact of climate change (McKie, 2013). Pneumonia, the leading killer of children, has been reported responsible for 1.3 million deaths in children aged under five years in 2011 (Walker et al., 2013), and the global burden of childhood pneumonia may continue to rise due to the Earth's increasing average surface temperature (Walker et al., 2013), though the true scale of the association between temperature and childhood pneumonia is largely unknown.

Persistent extreme temperatures (i.e., heat waves and cold spells) occur across the globe and heat waves are projected to become more frequent and intense in the future (Meehl and Tebaldi, 2004), posing a huge challenge to children's well-being (Xu et al., 2013c). Existing literature indicates that the effects of persistent extreme temperatures on human health can be attributable to the independent effects of daily ambient temperature (main effect) and of persistent periods of heat and cold (added effect) (Anderson and Bell, 2009; Hajat et al., 2006). During periods of persistent extreme temperatures, children are more likely to stay indoors, which may increase crowding and their exposure to biomass fuel smoke from cooking, possibly resulting in a higher risk of getting pneumonia. However, to our best knowledge, few data are available on the effects of heat waves or cold spells on childhood pneumonia, and no study has examined whether heat waves or cold spells have an added effect on childhood pneumonia.

Epidemiological studies examining the effect of temperature on health tend to use temperature from one ground-monitoring site or the average from several ground-monitoring sites, which might result in measurement bias, especially for those areas without extensive monitoring sites, because temperature across one city is spatially variable (Zhang et al., 2011), and temperatures in urban areas are normally higher than those in rural areas because of the urban heat island (Laaidi et al., 2012). Satellite remote sensing data can substantially supplement ground monitoring networks to

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quantify the effect of exposure to environmental hazards on health (Wang et al., 2013). The fundamental bias satellite remote sensing data reduces is exposure error reduction due to better coverage and higher spatial resolution. If using weather station data, researchers would probably need to draw a buffer and assign everybody's temperature exposure to the readings at this central station. Satellite data, on the other hand, are gridded at a pretty high spatial resolution so that the exposure estimates can be more accurate. In addition, land surface temperature is different from air temperature in that it considers the impact of direct solar radiation and the surface long-wave radiation, so someone will feel hotter under the sun than in the shade even though the difference in air temperature between under the sun and in the shade is smaller, and thus it can be strongly related to heat-related morbidity and mortality. Although satellite remote sensing data have been successfully used to link the relationship between air pollution and acute health outcomes (Evans et al., 2013; Wang et al., 2013), it has been scarcely applied to assess the impact of temperature on human health (Estes et al., 2009).

This study used the data on satellite remote sensing temperature and emergency department visits (EDVs) for childhood pneumonia in Brisbane, Australia, from 2001 to 2010 and aimed to minimize the measurement bias and answer three research questions: (i) What is the relationship between temperature and EDVs for childhood pneumonia? (ii) Is there any added effect due to heat waves and cold spells? (iii) Whether there is any significant change over time in the effect of temperature on childhood pneumonia across the study period?

2. Methods

2.1. Data collection

2.1.1. Health data

Brisbane is the capital city of Queensland, Australia. It has a subtropical climate and rarely experiences very cold temperatures. The daily EDV data from January 1st 2001 to December 31st 2010 classified according to the International Classification of Diseases, 9th version and10th version (ICD 9 and 10), were obtained from Queensland Health. Those coded as pneumonia (ICD 9 codes: 480–486; ICD 10 codes: J12–J18) in children aged 0–14 years were selected.

2.1.2. Ground-monitoring data

Daily weather data, including rainfall and relative humidity, were supplied by the Australian Bureau of Meteorology. Data on air pollutants, including daily average particular matter $\leq 10\,\mu m$ (PM_{10}) ($\mu g/m^3$), daily average nitrogen dioxide (NO_2) ($\mu g/m^3$) and daily average ozone (O_3) (ppb), were obtained from the Queensland Department of Environment and Heritage Protection (former Queensland Environmental Protection Agency).

2.1.3. Satellite remote sensing temperature data

Land surface temperature (LST) is the mean radiative skin temperature of an area of land resulting from the energy balance between solar heating and land-atmosphere cooling. LST is more closely related to the physiological activities of leaves, soil moisture, and near-surface meteorology. Therefore, it has stronger

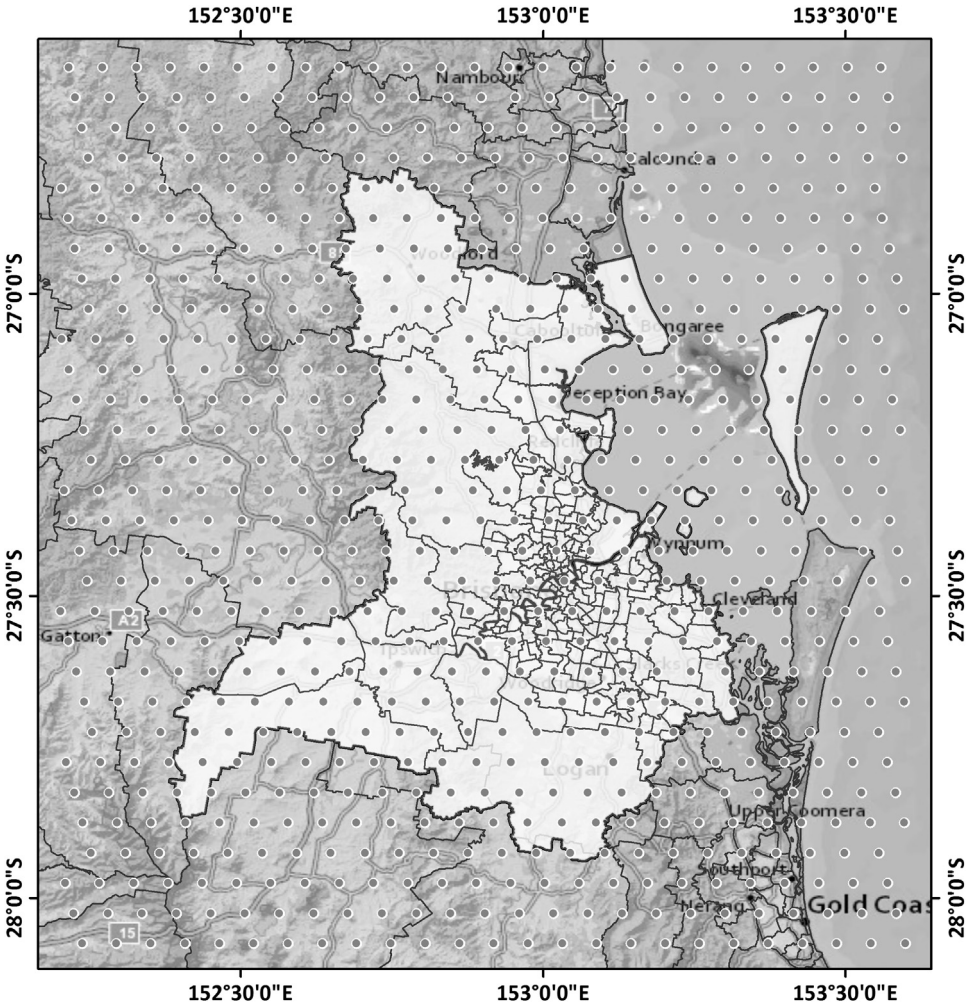

Fig. 1. The areas where satellite remote sensing temperature data were collected.